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URANIUM RESERVES, RESOURCES, AND PRODUCTION

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The President's Energy Resources Council (ERC) has the responsibility for coordination of Administration policies and programs relating to energy. Because of the important role envisioned for nuclear power in the next decade and beyond, the ERC established a nuclear subcommittee to coordinate Federal nuclear policy and programs to assure that issues which arise are treated via an integrated Government effort. This paper draws on the technical, economic, and environmental expertise of the Federal agencies who are ERC members to provide a brief review of United States uranium reserves, resources, and production.

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FOREWORD

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This paper draws on the technical, economic, and environmental expertise of the Federal agencies who are ERC members to provide a brief review of United States uranium reserves, resources, and production.

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URANIUM RESERVES, RESOURCES, AND PRODUCTION

Summary

- Detailed studies of the national energy situation and outlook[1] indicate a strong need for:
  - Effective conservation to reduce demand growth and vigorous expansion of our use of domestic fuels, and
  - Expansion of both coal-based and nuclear power generation as vital elements of our effort to avoid greater reliance on imported oil.
- Realization of projected growth of commercial nuclear power requires assurance of timely availability and production of adequate uranium to fuel existing, planned, and needed additional reactors for their full operating lifetimes.
- Adequacy of uranium supply is of particular concern to utilities and State regulatory commissions faced with pending decisions respecting the type of generating capacity needed to serve growing demand for electricity.
- This paper summarizes the uranium information available from those Federal agencies which are ERC members and which have the competence to report on the uranium supply outlook.

- Two distinct questions are apparent:
  - o Is there enough uranium in the ground (domestic natural resources) to support a large national nuclear power program?
  - o Is uranium likely to be discovered, developed, and produced in sufficient quantities and in time to meet the demand?
- Available data indicate that there are sufficient economically recoverable uranium resources on which to base an expanding nuclear program. The adequacy of uranium to provide fuel (over their 30-year lifetime) for all existing, planned, and additional reactors which may be placed into service by 1990, is a reasonable national planning assumption.
- To supply those reactors expected to be placed into service beyond 1990, the adequacy of uranium resources will depend on:
  - o Results of additional study of United States resources and expanding exploration which are expected to result in increases in the estimated resources, and
  - o The development and introduction of reactors with improved efficiency of uranium utilization (e.g., breeders).

- Federal programs are underway to better define the overall United States uranium resource base and to identify promising areas for industrial exploratory effort.
- Respecting production capacity, the possibility does exist for short-term uranium supply problems if timely industrial decisions to expand domestic uranium mining and milling capacity are not forthcoming. Delays in adding enrichment capacity and delays in achieving recycle of uranium or plutonium would increase the possibility of such a shortage. Legislative action, Federal programs, and regulatory decisions are in process in these areas. In the event such temporary domestic shortages occur, they might be relieved by imported uranium or draw down on available inventories. However, recent industry announcements give cause for optimism that industrial expansion of domestic uranium mining and milling capacity will be adequate so that reliance on imports would be unnecessary.

Resources

Uranium is a moderately abundant element in the earth's crust[2] and, because of its chemical characteristics, it is found in a wide variety of geological situations. Practically no geologic environment is totally free of uranium.

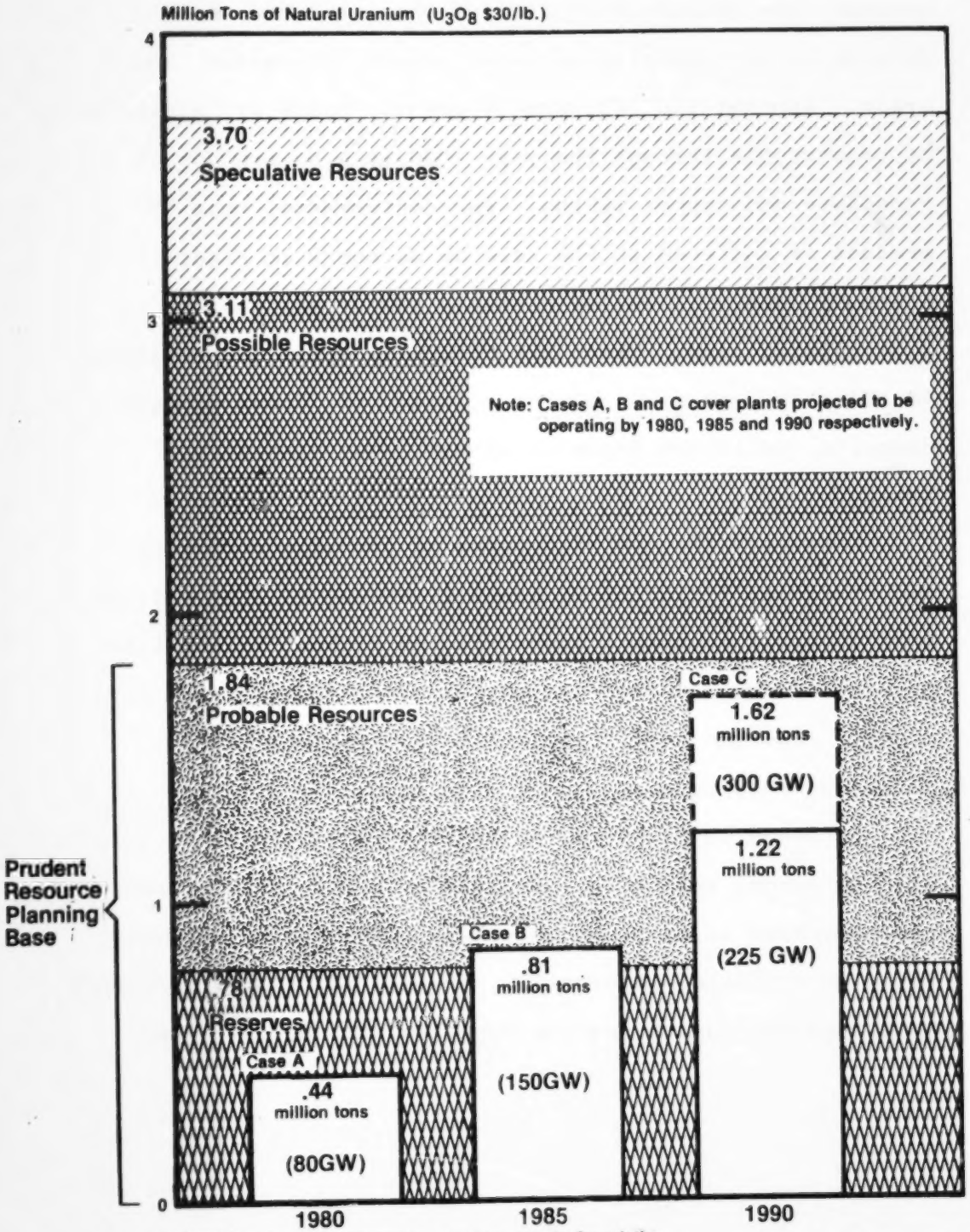
Most of the uranium produced to date has come from the Colorado Plateau--mostly New Mexico--and the Wyoming basins. Much of the known higher grade resources are in these areas. Uranium has been found in many other parts of the United States, and there is reason to believe that additional areas containing important uranium resources will be discovered.

In order to reduce uncertainty as to the magnitude of the Nation's uranium resources and to provide a broader base of knowledge of the how, where, and why of uranium occurrences, the Department of Interior, U. S. Geological Survey (USGS), and the Energy Research and Development Administration (ERDA) are engaged in continuing and extensive investigation and evaluation of the extent of domestic uranium resources[3 4].

These programs are aimed at providing more complete evaluation of domestic uranium resources in order to guide potential producers and consumers and to help assure timely discovery, delineation, and development of additional supplies. As part of this continuing effort, ERDA carries out a National Uranium Resource Evaluation Program, which includes annual reassessment of uranium resources. The estimate of resources as of January 1, 1976, is shown in Figure 1.

Figure 1

Cumulative Lifetime Consumption of Uranium by Nuclear Reactors and ERDA Estimates of Reserves



Capacity Shown is Beginning of Year and is Cumulative

Solid Line is FEA Projection in *National Energy Outlook*. Dashed Line is ERDA Upper Range Projection. Source Estimates: Ref. 5.

Four categories of uranium resources are shown in Figure 1. Reserves of uranium oxide (U_3O_8), the standard measure, are estimated at 640,000 tons and are well defined in ore deposits of known extent, character, and grade. Another 140,000 tons of uranium oxide are estimated to be recoverable through the year 2000 as a by product of phosphate and copper mining. For convenience, this by-product is included in the reserve category in Figure 1. A second category, called probable resources, amounts to 1.06 million tons. These are resources which are estimated to exist as extensions of, or adjacent to, known uranium deposits, or in new deposits within known mineralized trends.

Together, the two categories of probable resources and reserves, including by product, amount to 1.84 million tons of uranium oxide. These are the highest reliability portion of total United States resources and serve as a prudent resource base for planning nuclear powerplant construction programs.

As shown in Figure 1, an additional 1.86 million tons of uranium oxide, defined as possible and speculative resources and estimated to exist on the basis of geologic judgment using more limited information, provide additional assurance that adequate future uranium supplies will be developed.

The reserves and probable resources (the prudent resource planning base) shown in Figure 1 are about 6.5 times greater than the 280,000 tons of uranium oxide which have already been produced in the United States during the past 25 years. The estimated resources include uranium which can be produced at a cost of up to $30 per pound of recovered uranium oxide in today's dollars and based on today's technology. The costs are future costs and exclude past expenditures. Thus, this $30 per pound figure should not be confused with total cost or sales prices.

There are much greater resources of uranium then shown in Figure 1, if material of higher future cost than $30 per pound is considered. Thus, additional quantities of uranium could be added to the resource base as the cost of fuels rises and it becomes economically attractive to buy uranium at higher costs.

For example, large quantities of uranium contained in the Chattanooga shale of the southeastern United States are not included in the ERDA $30 estimates although they may become economically competitive. Thus, Figure 1 does not reflect total domestic uranium resources.

Demand

The adequacy of the presently estimated uranium resource base to support any level of nuclear capacity is assessed by comparing resource quantities (supply) with the projected consumption of uranium for production of electricity (demand).

The average 1,000 megawatt (1 GW) nuclear powerplant will consume from 4,000 to 6,000 tons of uranium throughout its entire lifetime of about 30 years. The exact quantity will depend on a number of factors discussed elsewhere in this paper. Thus, the present estimate of reserves and probable resources (1.84 million tons) would be sufficient to fuel at least 300 1,000-megawatt reactors over their entire lifetimes.

As indicated in Figure 1, this exceeds the nuclear capacity expected to be installed by 1990. In short, there appear to be adequate uranium resources in the United States to meet planned needs for many years to come.

In addition, it is probable that more uranium will be discovered in the years ahead, which would further extend the availability of uranium.

Many factors will affect the actual growth in uranium demand--overall demand for electricity, the rate at which nuclear plants come on-line, the relative economics of other energy sources,and a multitude of other political, social, economic, and environmental considerations.

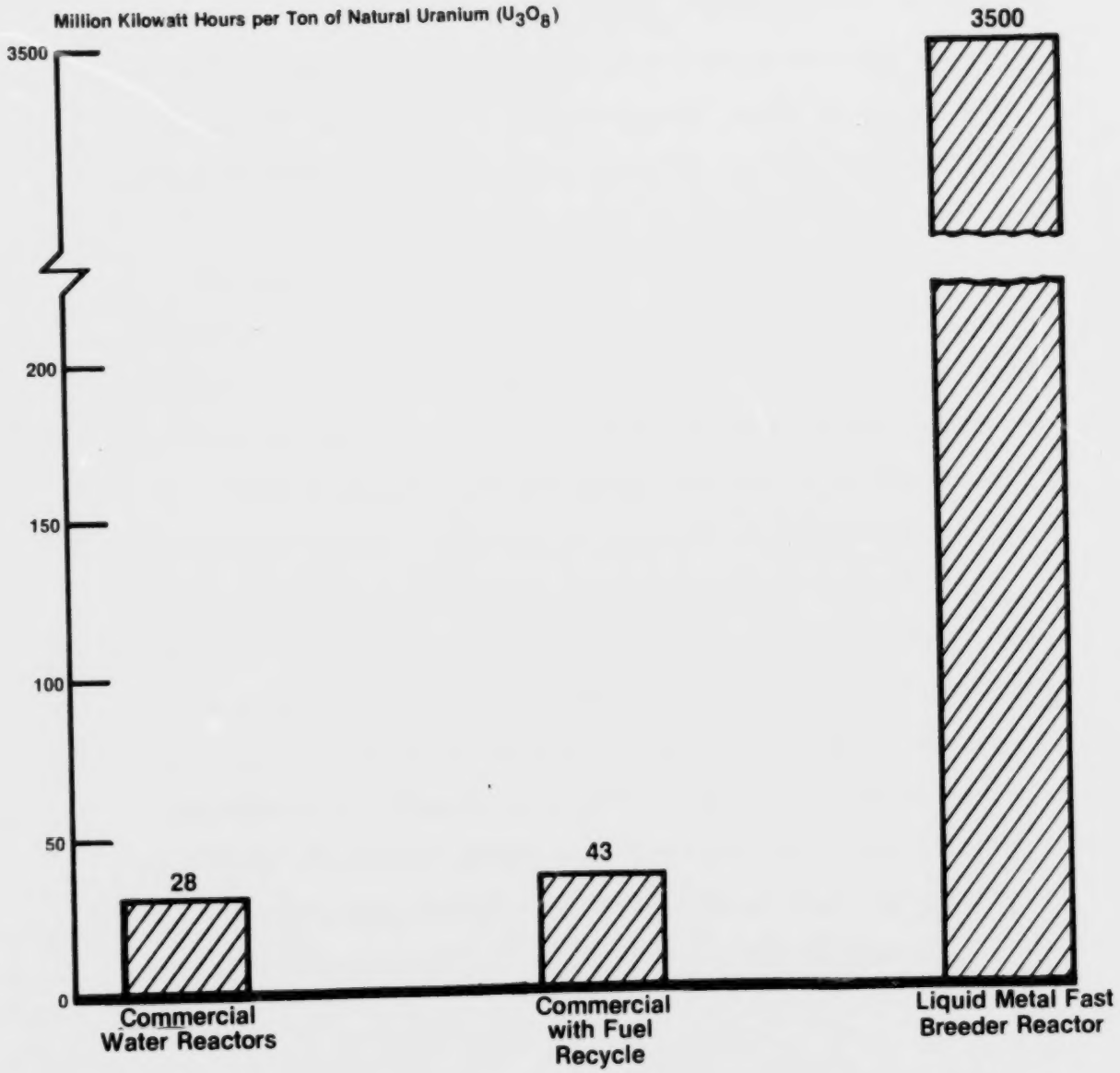
Other factors affect the amount of uranium required by each reactor, in turn affecting overall uranium demand. The enrichment process, which produces slightly enriched uranium and leaves a stream of depleted uranium known as "tails," can be adjusted to vary the amount of uranium feed

required to produce a desired amount of nuclear fuel. Decreasing the tails assay at which the plant operates results in a decrease in the amount of natural uranium required. For example, if an enrichment tails assay of 0.2 percent of U_{235} and no recycle of uranium or plutonium is assumed, a 1000 MWe plant would need 5,400 tons of U_3O_8 over its lifetime. (Consumption estimates of Figure 1 are based on these assumptions.) Increasing the tails to .25 percent would increase natural uranium demand above 5,400 tons per reactor by about 9 percent.

Reprocessing of spent fuel to recover and recycle unused uranium would reduce new natural uranium requirements below 5,400 tons per reactor by about 17 percent. Similarly, recycling the plutonium which is created as the uranium is consumed in a reactor would further reduce natural uranium requirements another 17 percent. These reductions in fuel requirements would increase the nuclear capacity that could be supported by a given uranium supply. Potential savings are indicated in Figure 2, which shows the electric energy obtainable per ton of natural uranium.

As shown in Figure 2, the best method for improving the utilization of our natural uranium resources is the liquid metal fast breeder reactor (LMFBR), now under development. By converting uranium 238 to plutonium, a breeder

Figure 2
Relative Fuel Efficiencies of Various Nuclear Reactors



Source Ref. 6

reactor generates more fissionable fuel than it consumes. The LMFBR would thus be able to utilize the stockpile of uranium tails, which--as previously mentioned--is a product of the enrichment process necessary for present generation reactors. Current ERDA plans call for demonstration of the breeder as a safe, reliable, and environmentally sound energy producer by 1987. If these plans are successful, the breeder would then be available for commercial application. Development of a commercial breeder could make uranium our most abundant domestic energy source and would expand our ability to utilize our present uranium resources by a factor of about 70.

Annual Production Capacity (Supply) versus Annual Demand

Current estimates indicate that the annual demand for natural uranium will double within the next 10 years and will double again during the following 10 years. This will require a major expansion of production capacity by the uranium industry over the next 20 years.

Uranium is mined by both underground and open pit methods. The uranium ore is processed in a mill to produce uranium concentrate which is then converted into uranium hexafluoride, UF_6. The UF_6 is then sent to an isotope separation (enrichment) plant where the content of the fissile isotope, U_{235}, in natural uranium is increased. The

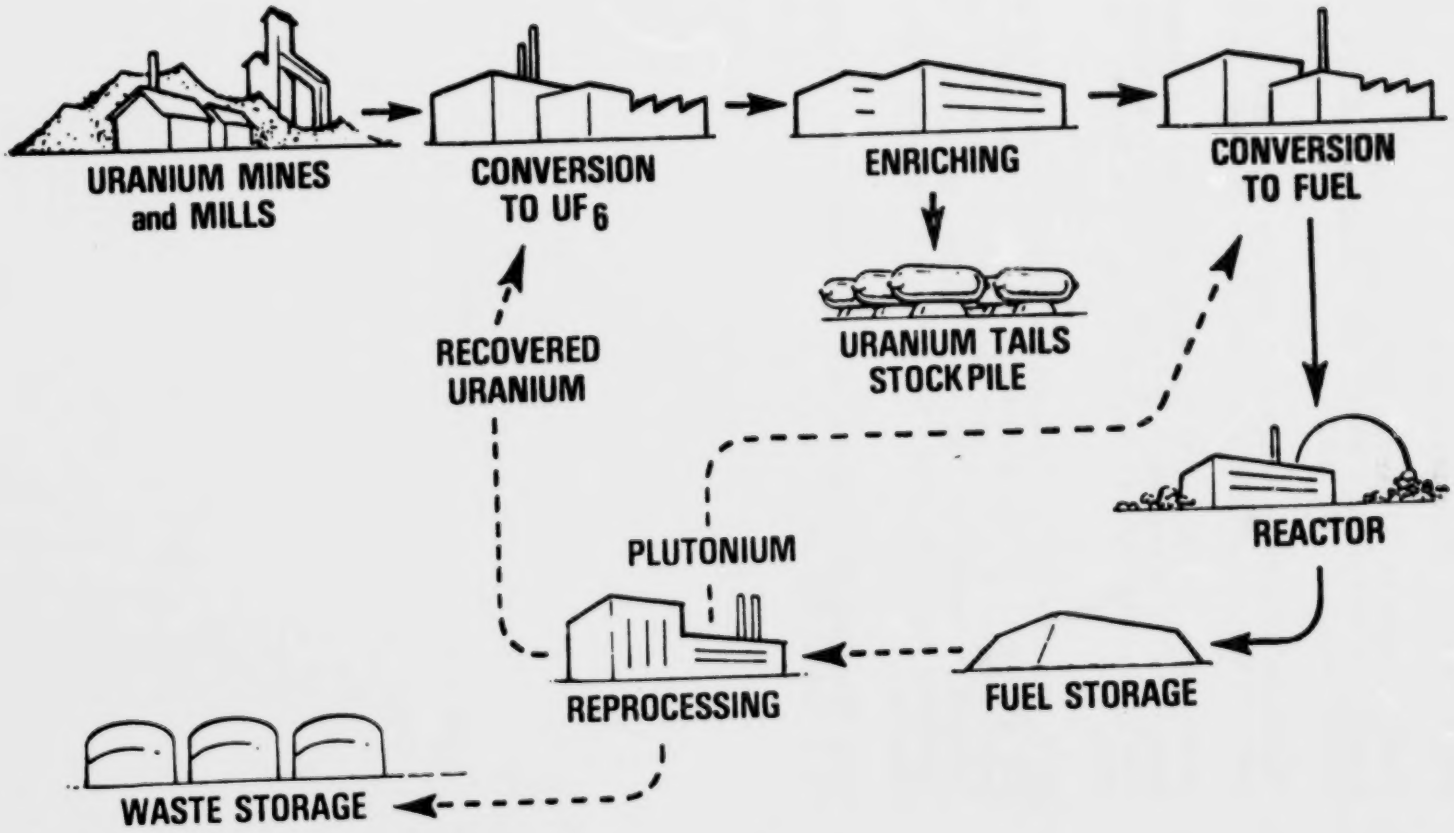
enriched uranium is then sent to a fuel fabricator where it is converted to uranium oxide and then formed into pellets which are fabricated into fuel elements for a reactor. The light water nuclear fuel cycle is shown in Figure 3.

Historically, uranium production has been capable of rapid expansion. From 1955 to 1960, uranium concentrate production expanded around sixfold, from 3,000 tons per year to 18,000 tons per year. The peak production year for uranium was 1960, as subsequent reduced demand resulted in production cutbacks. During 1975, uranium production was 11,600 tons, significantly below production capacity.

In response to increased demand, the uranium industry has reported plans to expand production capacity by the late 1970's to about 25,000 tons per year. Plans and commitments for new mines and mills must continue to be made in order to assure a continuing adequate uranium supply. Expansions of production over the long term will be dependent not only on adequate prices, a growing demand, and mine and mill expenditures, but also on expanding uranium exploration programs.

FIGURE 3

The Light Water Reactor Nuclear Fuel Cycle



SOURCE: Ref. 1

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